Vol. 10, Communication 250 (Piddlesden: The Concentration of Latex by Centrifugal Machines)

THE JOURNAL OF THE RUBBER RESEARCH INSTITUTE OF MALAYA

IMPERIAL MYCOLOGICAL INSTITUTE
5 NOV 1940

AUGUST 1940

Published by
The Rubber Research Institute of Malaya
and printed by
Kyle, Palmer & Co., Ltd.,
Kuala Lumpur, F.M.S.

Edited by H. J. Page on behalf of the Board of the
Rubber Research Institute of Malaya.

THE CONCENTRATION OF LATEX BY CENTRIFUGAL MACHINES*

BY

J. H. PIDDLESDEN

Summary

The concentration of rubber latex is first reviewed as a general problem. This is followed by an account of the experimental work carried out at the Rubber Research Institute of Malaya to test the performance of commercial machines available for operating this process. In the last section the practical aspects of the process are reviewed from the point of view of a plantation-rubber producer in the East.

Rubber latex has become a very important raw material and finds many applications, ranging from the proofing of fabrics and impregnation of paper to the manufacture of elastic threads, can-sealing compounds, adhesives and upholstery. A large amount of research work has been carried out in the East with a view to supplying preserved latex suitable for these processes. The latex as it leaves the tree has an average dry rubber content of about 33 to 35 per cent and is so unstable that it will coagulate within a few hours, unless preservative is added. Ammonia was found to be a suitable preservative and in spite of the continued search for new materials it remains in general use. The problem of concentrating the latex to avoid the shipment of surplus water arose early. Three methods for carrying out this operation were developed, namely, centrifugal concentration, creaming by the addition of gums and mucilages, and evaporation. A fourth method, utilising the phenomena of electrodialysis, has recently been the subject of commercial development. The advent of concentrated latex widened the field of latex applications since the concentrated products found uses for which preserved field latex was not suitable. For many processes the properties and applications of the latex or concentrate are now perhaps more important than the question of shipping cost. Various types of product, described briefly below, are obtained from the different processes of concentration.

EVAPORATED LATEX

The evaporation method for concentrating latex was developed by the Metallgesellschaft A.G. under patent protection (K.D.P.

* This paper is substantially as prepared for presentation at the Rubber Congress scheduled to be held in Paris on 17-19 May 1940.

Ltd., 1926). The original process involved the gentle heating of latex, to which caustic alkali and soaps had been added, in horizontal rotating drums through which a current of air was passed. The product, which was a very stable paste and reverted to latex on dilution with water, was sold under the trade name Revertex. It contained about 68 per cent of dry rubber, and in addition to the alkali and stabiliser it contained all the serum solids originally present in the latex. Later a vacuum evaporation process was developed which displaced the earlier one (Metallgesellschaft A.G., 1932), and there are now several grades of Revertex available including a grade containing only ammonia as preservative, and one with reduced serum-solid content, prepared by partially concentrating the latex by other means before evaporation. In general Revertex may be characterised as having a higher serum-solids content than other forms of concentrate.

Creamed Latex

Creamed latex concentrate is prepared by mixing into the field latex preserved with ammonia a certain amount of a suitable colloid, and allowing the mixture to stand until it separates under the action of gravity into two layers. The upper layer or cream contains most of the rubber together with some of the added colloid, and a proportion of the serum solids, while the lower layer contains very little rubber and the bulk of the serum solids. This process was protected by the Traube (1924) patent and has been developed commercially mainly by the United States Rubber Company on their Sumatra plantations, although a very large amount of research has been carried out, and numerous patents have been obtained by workers outside of that organisation. The mechanism of the process has not been completely elucidated. Latex consists of a very fine dispersion of rubber particles in an aqueous medium. These particles are sufficiently small to be affected by molecular bombardment which keeps them in motion, or Brownian movement, and prevents them from separating under the action of gravitational forces. The added colloid in some way prevents the Brownian movement of the rubber particles and enlarges them either by absorption on to the particles or by causing them to form loose aggregates so that they rise fairly rapidly under the action of gravity.

Latex Concentrated by Centrifugal Machine

This process consists of subjecting the latex to a centrifugal force many times greater than gravity in a suitable machine. The Brownian movement can be overcome in this way and the particles caused to segregate into one fraction of the liquid, without affecting

their electric charge or degree of aggregation. This method for separating suspended particles of liquid or solid from another liquid has long been known and applied in many fields but the major patent covering its application to rubber latex was obtained by Utermark (1923) and commercial development in the Far East has been carried out mainly by the Dunlop Rubber Company in co-operation with the De Laval Separator A.B. of Stockholm. The products of this process are a concentrate containing about 60 per cent of dry rubber together with a small portion of the serum solids, and a dilute or skim fraction containing from 2 to 10 per cent of dry rubber together with the bulk of the serum solids. The centrifuged concentrate is in many ways similar to latex cream, the main difference being the small amount of added colloid that the latter contains and the effect of this on the physical properties of the latex. This effect is not large and has not been completely explained, and the difference is often tersely expressed by latex users who say that creamed and centrifuged latex " process differently." Vigorous research programmes are being pursued in an attempt to explain and overcome this difference. The two products are likely to prove very close competitors for most latex applications, although at present centrifuged concentrate is perhaps the more popular.

Latex concentrated by Electrodialysis

A new method which is now being developed by the Dunlop Rubber Company is known as the Semperit process and the original patents were taken out by the Oesterreichisch-Amerikanische Gummiwerke A.G. (Semperit, 1938). The process is fundamentally one of creaming promoted by electrical means instead of by the addition of colloidal creaming agents and the product would be expected to resemble centrifuged concentrate very closely. It is claimed that with this process much less rubber is left in the serum or skim layer than is the case with the skim from centrifugal separators.

Centrifugal Machines

Theory of Separation

A particle suspended in a fluid medium tends to move with a constant velocity which may be expressed as

$$V = \frac{2\ gr^2}{9\ \eta}\ (d_1 - d_2) - \text{Stokes Law}$$

Where V is the velocity of the particle

r is the radius of the particle

d_1 is the density of the particle

d_2 is the density of the liquid
g is the gravitational acceleration
η is the viscosity of the liquid.

It is at once apparent that the velocity of the particle through the suspending medium may be increased, by increasing the radius; by increasing the density difference; by reducing the viscosity of the fluid; or finally by using some accelerating force more powerful than gravity. The presence of ammonia reduces the viscosity and this material therefore has a useful function in addition to its preservative action. Latex before concentration has a fairly low viscosity so that there is little scope for improving the value of V by this means. Since it is not desired to alter the physical properties of the latex no attempt should be made to alter the particle size or density and these factors are assumed to be non-variable for the purposes of this discussion. Thus in order to increase the value of V in the Stokes' formula there remains only the possibility of replacing gravity by a more powerful separating force, and the centrifugal machine offers a ready means of doing this.

Centrifugal acceleration (f) on a rotating particle $=\omega^2 R$, where ω is angular velocity $=2\pi n$, where n is revolutions per second. R is the radius of rotation.

The centrifugal acceleration can be expressed as a multiple of gravitational acceleration (g) and the separating power of a machine is often described in this way. Let this factor be C.

$$\text{Thus } C=\frac{f}{g}=\frac{(2\pi n)^2 R}{g}$$

At a point six inches from the centre of a machine rotating at 6,000 r.p.m. $C=\frac{(2\pi \times 100)^2\ 0.5}{32}=6{,}160.$

Thus the velocity of separation of a particle under these conditions is over six thousand times greater than under the action of gravity alone. This elementary analysis gives a very incomplete picture of what actually occurs when latex is separated in a centrifugal machine. Centrifugal acceleration acts outwards from the centre of rotation, and the normal action of a centrifugal machine on a suspension of particles heavier than the liquid medium is to throw out the suspended particles towards the periphery of the bowl. In latex however the suspended rubber particles are lighter than the serum, and are thus thrown outwards less violently than the serum so that concentrate accumulates at the centre of the bowl, and serum at the rim. The particles vary in size and the large particles separate more readily than the smaller ones. The

force on the particle increases with increasing distance from the centre of rotation of the bowl, thus as the serum flows outwards from the centre the rubber particles tend to be removed in order of size and at the same time the remaining particles in the serum become subjected to an increasing force. The viscosity of latex increases very rapidly with increasing dry rubber content until it reaches a point at which the latex will not flow. Thus in the concentrate the particle velocity falls rapidly and the tendency for further concentration is reduced by the increasing viscosity and diminishing separating force as the concentrate flows towards the centre of the bowl.

It is very important in practice to ensure that over-concentration shall not occur, or the concentrate will cease to flow and will choke the bowl. The distance the rubber particle moves relative to the liquid will depend on the time for which it is subjected to the separating force, so that in order to remove as much rubber as possible from the serum this should remain in the bowl as long as possible, while the concentrate should be removed as rapidly as possible after it has reached the desired dry rubber content. If a rotating bowl is fed continuously with latex, concentrate will collect at the centre and may be withdrawn while a dilute skim fraction may be withdrawn from the circumference, and somewhere between these two points there will be a "neutral layer" at which the latex has the same dry rubber content as the incoming feed material. The feed should obviously be introduced at this point, and here the centrifugal force should be as high as possible to secure the initial major separation rapidly. The neutral layer should be near to the centre of the bowl so that the concentrate, to avoid over-concentration, can quickly flow to a region of less force and thence by a short and easy course out of the machine. The bowl should be as large as practicable and the dilute latex should be made to follow a devious course to retain it in the bowl as long as possible, in order to remove the maximum amount of rubber from the skim fraction.

If there were an outlet at the circumference of the bowl the liquid would obviously issue with terrific force and it is therefore necessary to relieve the applied force before allowing the liquid to escape. This is done by conducting the serum back through a separate channel towards the centre of the bowl so that the pressure is counterbalanced on the principle of the U tube. In practice the horizontal distances of the discharge points from the vertical axis of rotation, for the two portions of the liquid, are adjusted to suit the small differences in the effective specific gravities. For a given rate of flow the proportions into which the liquid is divided can be controlled by adjusting the relative sizes

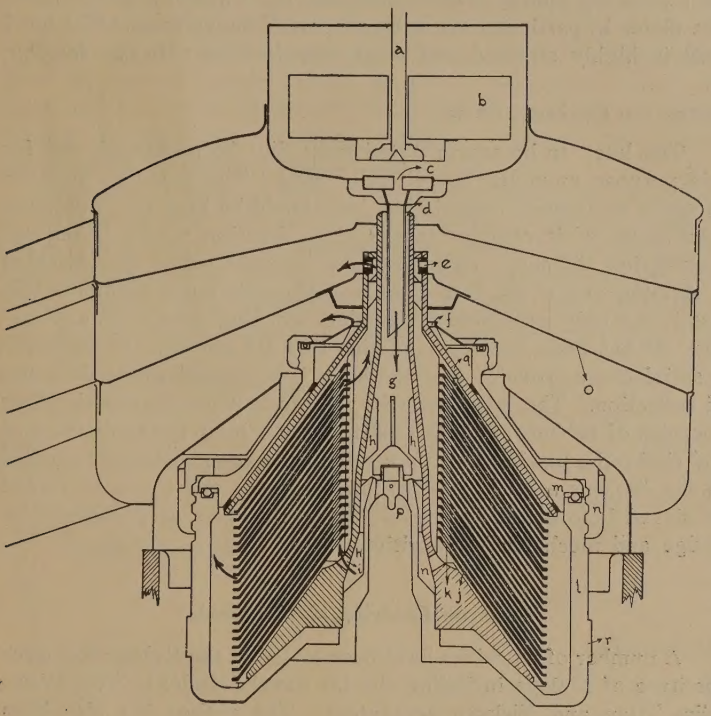
of the two outlets, or by varying the distances of the take-off points from the axis of rotation by screwing nozzles into or out of the neck of the machine. The feed rate can also be controlled and varied within limits. For a given setting of the outlets, a reduction of the rate of flow into the machine will increase the time for which the latex remains in the bowl and hence the degree of separation achieved. The foregoing outlines the underlying principles of latex concentration by centrifugal means and actual machine designs should now be considered.

Design of Separators

Fig. 1 shews diagrammatically a typical separator bowl. Latex enters the central tube under a constant hydrostatic head, usually controlled by a float valve, and is led to the bottom of the bowl. The central tube is usually tapered outwards from the top and the lower end is a conical piece which fits on to the bottom of the bowl and has radial holes through which the latex discharges into the bowl, approximately at the position of the neutral layer. Fins are provided in the feed tube so that the latex is set rotating and can be discharged into the bowl with approximately the same rotational velocity as that of the liquor in the bowl at this point, thus avoiding shock and turbulence. The separating space is filled with a pile of conical plates or discs of sheet metal, perforated with holes to correspond with those in the distributor or feed tube. They are located either by splines on the outside of the central distributor or by fins on the inside of the bowl wall. These discs divide the liquid in the bowl into thin films and since separation occurs in a horizontal direction they reduce the distance that the particles have to travel to enter the concentrate to a millimetre or less. They also provide conducting paths for the flow of liquid.

Concentrate flows upwards between the plates to the annular space between the distributor and the edges of the plates, thence upwards between the distributor and the neck of the top plate to the discharge orifices where it is thrown out and collected in a tray. The serum passes downwards between the plates into the space between their edges and the bowl shell which acts as a sludge collecting zone. The serum then passes up between the top plate and the bowl cover to outlets where it is discharged and collected like the cream. The bowl is driven by a central vertical spindle which fits into its base. The spindle in turn is driven through a worm gear usually of 10 : 1 ratio, by a horizontal shaft carried in the machine pedestal and having at one end a pulley containing a centrifugal clutch which is connected by belt to an electric motor or line shafting. The clutch is essential, for the bowl when full of liquid is very heavy and runs at high speeds and if it were

coupled positively to the drive the shock on starting or stopping would be very great.



DIAGRAMMATIC SECTION OF BOWL

a. Feed pipe
b. Feed control float
c. Inlet orifice
d. Overflow
e. Cream discharge
f. Skim discharge
g. Distributor
h. " vanes
i Discharge to bowl
j. Separator plates
k. Holes in separator plates
l. Bowl
m. " cover
n. Locking ring
o. Collecting trays
p. Driving tongue
q. Top plate
r. Brake rim

Fig. 1

The machine must be designed to resist corrosion by ammonia solution and to prevent contamination of the latex. It is particularly important that no copper or brass parts should be used since minute traces of copper have severe deleterious effects on the rubber. Tinned copper or brass should also be avoided since

the tin coating is likely to rub off in use. Usually the bowl, distributor and collecting trays, are made of tinned steel while the separating plates, nozzles and small parts are of stainless steel. The plates in particular are subject to very heavy wear. The bowl shell is highly stressed and must therefore be a heavy forging.

Latex for Concentration

The latex to be concentrated must first be preserved, and for this purpose ammonia is generally used. The quantity must be adequate to prevent coagulation, but should be kept to a minimum since most of it remains in the skim fraction where it renders coagulation difficult. Ammonia also escapes while the machine is running and if the feed latex contains too much ammonia this loss is not only expensive but renders working conditions unpleasant. It has been found in practice that 0.3 per cent of ammonia is satisfactory provided that the latex is separated within 24 hours of collection. The latex must be free from "pre-coagulation" or floccules of rubber, as these tend to form a lump in the distributor and choke the machine. To prevent this, ammonia should be added to the latex as early as possible after tapping and the latex should be sieved before use. It should also be as free as possible from sludge and mechanical impurities.

Tests on Centrifugal Machines

A number of machines have been tested at the Rubber Research Institute of Malaya including the De Laval (Model L 770), Westfalia, Titan and Vickcen separators. The author has also been able to observe the De Laval (model L 1970) and Sharples machines in operation on estates.*

De Laval Machine—Model L 770

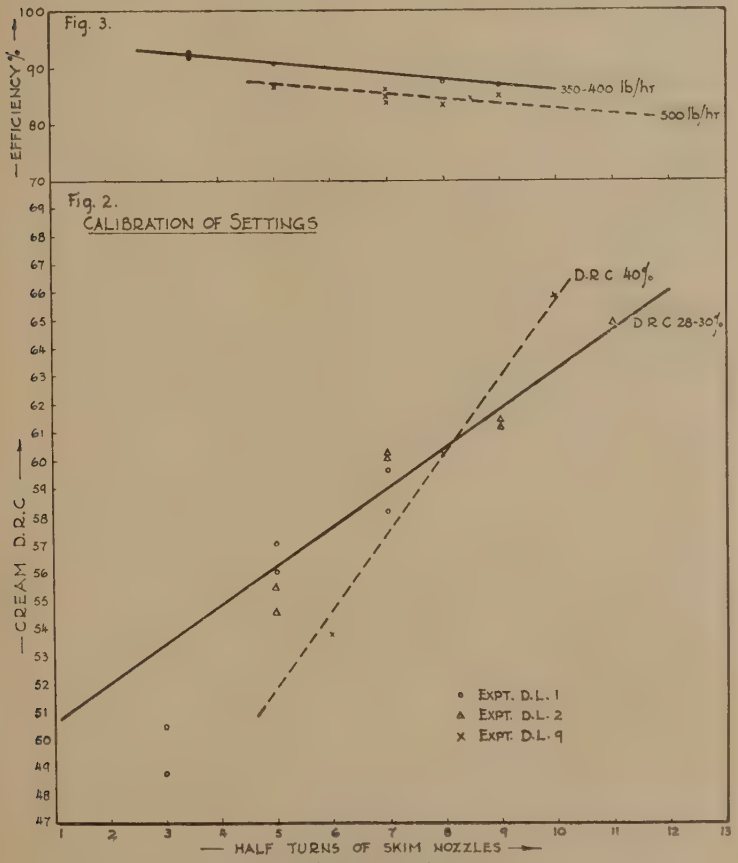
An experimental machine manufactured by the Aktiebolaget Separator of Stockholm was installed for testing in the laboratories of the Rubber Research Institute and experiments were carried out in collaboration with a research engineer from the manufacturers. The machine was the prototype of the present De-Laval Model L 770 sold for latex concentration. The bowl was 11½ inches in internal diameter and 6½ inches deep, and contained fifty-two conical tinned steel separating plates. The machine was driven at 7,000 r.p.m.

---

* The Westfalia and Titan machines, being of German and Danish manufacture respectively, are not available at present (August 1940). The De Laval machines are of Swedish manufacture, and so these also may be difficult to obtain.

The present commercial model has a bowl of the same size and contains fifty-one stainless steel separating plates; it is driven at 8,000 r.p.m. The design differs from that shewn in figure 1 in that the separating plates are located on ribs on the inside of the bowl wall instead of on splines on the outside of the distributor. Thus the central annular space in which the cream collects is larger and free from all obstruction, which is an advantage when working at high concentrations where concentrate may form enough paste to choke a smaller space.

The rate of flow of latex into the machine was controlled by the feed orifice (cf. Fig. 1) which could readily be changed. Minor changes in the feed rate could be obtained by altering the height of the float in the cup. The cream was discharged at (e) through fixed radial orifices. The skim was also discharged



Figs. 2 & 3.

through radial orifices at (f) and control, effected by varying the projection of these nozzles in the neck of the tube, was recorded as the number of turns from the flush position, one full turn being one-sixteenth of an inch.

A number of experiments were carried out, but only those pertaining to the calibration of the settings and performance on ordinary ammoniated field latex fall within the scope of the present work. For the former purpose short tests were carried out and the results appear in Table I and are shown graphically in Fig. 2 (p. 86).

The efficiency is the weight of rubber in the cream as a percentage of the sum of the weights of rubber in the skim and cream as determined by dry rubber contents. This method is not entirely satisfactory since determination of dry rubber content in a skim poor in rubber is difficult and may give high results owing to the high proportion of protein precipitated. The figure is however useful for comparative purposes.

For the tests given in Table I two of the latices used had abnormally low dry rubber contents while the third was exceptionally high. They show that for the preparation of concentrate with 60 per cent dry rubber content the nozzle setting is almost independent of the dry rubber content of the feed latex, and a machine once set will deal with normal day-to-day variations in the field latex with very little adjustment. The results plotted in fig. 2 are somewhat irregular, as would be expected since for a given setting and given latex the throughput will affect the dry rubber content of the concentrate.

Figure 3 (p. 86) shews efficiency plotted against settings for two different throughputs, and as would be expected the efficiency falls with increasing feed rate.

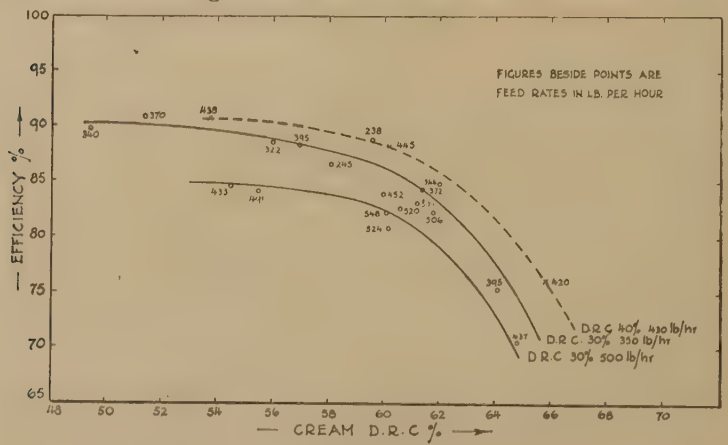


Fig. 4

TABLE I

Experiment No. ...	DL 1						DL 2							DL 9		
Feed latex d.r.c. ...	29.2						28.5							39.8		
Ammonia Content (per cent)	0.34						0.45							0.34		
Test No. ...	a	b	c	d	e	f	a	b	c	d	e	f	g	a	b	c
Skim Nozzle (half turns) ...	3	3	5	5	7	7	5	5	7	7	9	9	11	6	8	10
Time of run (mins.) ...	7.03	5.04	5.92	7.32	9.95	8.47	4.90	4.35	3.83	4.58	3.67	5.73	3.50	20	20	5
Concentrate (lb.) ...	23.0	15.5	18.5	18.0	16.8	14.8	15.5	15.8	14.3	14.0	12.8	14.3	8.3	95.0	97.0	19.5
Concentrate (d.r.c.) ...	51.4	48.7	57.0	56.0	59.6	58.1	54.5	55.5	60.1	60.0	61.2	61.4	64.8	53.7	60.2	65.8
Ammonia Content (per cent)	0.19	0.19	0.16	0.14	0.12	0.11	0.21	0.21	0.54	0.50	0.19	0.16	0.16	0.18	0.17	0.17
Skim (lb.) ...	20.2	13.0	20.5	21.3	21.0	19.8	19.8	19.8	20.8	20.5	20.3	21.3	17.3	51.0	51.5	15.5
Skim (d.r.c.) ...	4.2	5.08	5.27	4.79	4.64	5.94	6.41	6.82	7.46	6.53	6.58	6.21	11.4	7.14	11.62	22.5
Ammonia Content (per cent)	0.36	0.35	0.35	0.31	0.31	0.29	0.51	0.49	0.49	0.47	0.47	0.46	0.42	0.45	0.45	0.43
Throughput (lb./hr.) ...	370	340	395	322	228	245	433	491	548	452	541	373	434	438	445	420
Efficiency (per cent) ...	93.2	91.9	90.7	90.9	91.2	88.0	87.0	87.3	84.7	86.0	85.4	86.9	73.3	93.3	90.7	78.6

TABLE II

Experiment No.	Feed Latex		Duration of Run (Mins.)	Concentrate			Skim			Throughput (lb./hr.)	Efficiency (per cent)	Remarks
	d.r.c. (per cent)	Ammonia (per cent)		Wt. (lb.)	d.r.c. (per cent)	Ammonia (per cent)	Wt. (lb.)	d.r.c. (per cent)	Ammonia (per cent)			
DL 4	28.4	0.31	150	475	61.8	0.14	791	6.73	0.34	506	84.7	Test stopped by exhaustion of latex supply. The bowl was dirty but would have run longer
DL 8	30.2	0.35	102	386	60.2	0.14	508	9.25	0.36	524	83.2	Latex in very poor state of preservation. Bowl did not choke but contained much sludge and coagulum
DL 11	30.7	0.35	170	620.5	60.1	0.17	841	8.23	0.47	516	84.3	Bowl choked with coagulum in distributor and was stopped when flow started from overflow

Figure 4 (p. 87), in which efficiency is plotted against the dry rubber content of the concentrate for different latices at different rates of flow, gives a very clear picture of the machine performance. The figures against each point give the feed rate for the particular test. Although the results are insufficient to average out the uncontrolled variables and define the curves accurately the general trend is quite clear. The results show an obvious advantage in using field latex of high dry rubber content.

The time the machine will run before cleaning becomes necessary is an important practical consideration. It depends on the condition of preservation of the latex and its freedom from dirt. In the tests carried out with this machine and reported in Table II no special precautions were taken and the conditions were less favourable than would obtain in normal estate practice, since the latex was collected on an estate where it was treated with a trace of sodium sulphite as preservative. It was then transported twelve miles by lorry, then ammoniated and stored overnight before use. Normally the ammonia would be introduced at the collecting point. This was done only in the last test (DL 11).

The figures quoted in Table II are important. They are typical of commercial operation, although they are below the average which should be obtainable in practice since the dry rubber content of the field latex was low and rather high rates of feed were used. Samples were taken at frequent intervals during each run and it was found that the performance of the machine remained practically constant for the first 2 to 2½ hours, and then fell off fairly rapidly, as is shewn in Table III which gives data obtained during experiment DL 11.

TABLE III

Experiment DL 11

	Average for first 30 minutes of run	Average for first 120 minutes of run	Average for last 20 minutes of run after 150 minutes
Concentrate d.r.c. ...	60.7	60.5	58.2
Skim d.r.c. ...	7.7	8.0	9.8
Throughput lb./hr. ...	515	520	524
Efficiency per cent ...	85.2	84.7	81.9

The tests shew that this machine could be expected to give concentrate of 60 per cent dry rubber content at 85 per cent efficiency from average field latex of about 33 per cent dry rubber content fed at the rate of 450 lb. per hour, and should run for 2½ hours before cleaning becomes necessary. The machine took 7½ minutes to reach full speed, and 5½ minutes to stop under the action of the brake. Dismantling, cleaning and reassembling the bowl occupied two men for 30 minutes. Thus each 2½ hours of running time was followed by a close-down period of 42 minutes.

The commercial machine has improved clutch and brakes and can be accelerated to full running speed in 3½ minutes and stopped in two minutes. It is designed so that the dirty bowl can be lifted bodily from the machine and replaced by a spare clean one. Thus if a spare bowl is available the total close-down period after each run can be reduced to ten minutes. The machine is rated to handle 450 lb. of latex per hour at 7,000 r.p.m. but may be safely run up to 8,000 r.p.m. and its performance should therefore be slightly better than that of the machine tested.

Westfalia Machine

The "Westfalia" machine is manufactured by Ramesohl and Schmidt A.G. of Oelde, Westfalia, Germany. The machine follows the conventional design shewn in Figure 1. The bowl is 14 inches in diameter and is designed to run at 8,000 r.p.m. Under the actual test conditions used the speed was 8,200 r.p.m. The 135 conical separating plates are of tinned steel. They are very closely packed, the space between them being approximately 0.02 inch whereas in the De Laval machines the space is of the order of 0.05 inch. The design differs from that shown in Figure 1 in that there is no separate overflow outlet and the overflow collecting tray is dispensed with. The skim outlets are fixed orifices bored to discharge tangentially. The cream discharges vertically upwards at (c) through the annular space between the distributor and a collar which is screwed into the neck of the top plate. The setting of the machine depends upon the internal diameter of this collar. Collars of the following sizes are supplied with the machine:—45, 50, 58, 59.5, 60.5 and 61.5 mm. diameter.

Calibration of the settings was carried out as before. It was found that only the first two collars (45 and 50 mm.) were suitable for producing 60 per cent concentrate; unfortunately no intermediate sizes were available. Table IV gives typical calibration results, from which it can be seen that 60 per cent concentrate is obtainable from poor field latex at feed rate of 450 lb. per hour, while with good field latex the rate of feed could be increased to 600 lb. per hour, or alternatively the dry rubber content of the

TABLE IV

Collar diameter (mm.)	Feed tube bore (mm.)	Feed d.r.c. (per cent)	Feed Rate (lb. per hour)	Concentrate d.r.c. (per cent)	Skim d.r.c. (per cent)	Efficiency (per cent)
58	7	30.1	433	54.1	1.91	97.2
59.5	7	30.1	478	53.3	1.99	97.6
60.5	7	28.9	410	50.1	2.52	96.1
50	7	28.9	458	59.3	2.41	96.4
50	5	28.3	195	65.2	2.17	95.6
50	8	39.2	595	57.4	3.79	96.8
50	7	38.7	465	60.5	3.12	97.0
45	7	28.3	488	60.4	2.94	94.7
45	7	30.5	471	61.5	2.42	95.9
45	7	38.2	440	62.8	3.19	96.6
45	8	37.6	590	60.2	3.95	95.9

concentrate could be increased to 62—63 per cent. The rubber content of the skim fraction was remarkably low and its determination was difficult. The normal method employed was to add to 50 gm. of the skim fraction in a glass dish 40 to 50 ml. of alcohol containing five per cent of acetic acid, the whole being gently stirred. After standing overnight the coagulum was removed and any small particles of rubber were filtered off and added to the coagulum which was rolled out, washed and dried to constant weight. The rubber so obtained was very tough and leathery and obviously contained a large proportion of non-rubber solids. An alternative method was tried in which 50 gm. of serum was digested with 10 ml. of 30 per cent sodium hydroxide solution before coagulation with formic acid. This gave a more normal rubber, the results averaging 22 per cent below those obtained by the first method, which was reflected as an improvement in the efficiency figures. This matter has been discussed in several papers (van Gils, 1939; Ten Broeck and Schrieke, 1940), but the results given in this paper were obtained by the original method. The efficiency was very high and in more than thirty tests with varying latices, not always with the optimum settings, the figure never fell below 94.5 per cent, and on tests with large quantities of latex under commercial conditions 96—97 per cent was obtained. Alteration of machine settings affected the dry rubber content of the concentrate and the throughput, but had little effect on the efficiency. Typical results for commercial-scale runs are given in Table V.

The performance of this machine, as with the De Laval, was fairly steady for the first part of the test, then deteriorated as the run progressed. For example in experiment WS 6, Table V, the rubber content of the concentrate remained nearly constant at 61.5 per cent for the first 1¼ hours whereas the portion collected in the last 12 minutes contained only 59.8 per cent of rubber. Similarly the rubber content of the skim remained nearly constant at just below 3 per cent for a long period, then rose to 3.5 per cent at the end of the test. Summarizing the results of these and other tests not reported in detail, it was concluded that with this machine field latex of 33 to 35 per cent dry rubber content could be concentrated to over 60 per cent dry rubber content with 95 per cent efficiency at the rate of 450 lb. per hour, and that an average run of at least three hours could be obtained before cleaning became necessary. With particularly good feed latex the throughput could be increased to 550 to 600 lb. per hour. The bowl took about nine minutes to reach operating speed and start discharging latex, and three minutes to stop. Allowing five minutes to change bowls a complete change-over could be carried out in 17 minutes if a spare bowl were available. It is necessary to allow

TABLE V

Experiment No.	Feed Latex		Duration of Run (Mins.)	Concentrate			Skim			Throughput (lb./hr.)	Efficiency (per cent)	Remarks
	d.r.c. (per cent)	Ammonia (per cent)		Wt. (lb.)	d.r.c. (per cent)	Ammonia (per cent)	Wt. (lb.)	d.r.c. (per cent)	Ammonia (per cent)			
WS 6	30.4	0.36	172	644.5	61.0	0.17	698.5	3.07	0.49	469	94.9	Bowl did not choke but contained much coagulum in distributor. Seedling latex, A.D. tapping
WS 9	34.3	0.34	180	690	62.4	0.16	594	3.64	0.44	428	95.2	- do -
WS 14	38.8	0.32	224.5	1016	61.2	0.21	648.5	4.01	0.50	445	96.1	Latex from new tapping cuts
WS 18	37.6	0.32	120	705	60.2	0.16	468.5	3.95	0.49	587	95.9	Latex from new source third-daily tapping
WS 22	38.7	0.30	180	852.5	59.8	0.14	506	3.63	0.40	453	96.6	Bowl not choked but very dirty. Latex from new source third-daily tapping

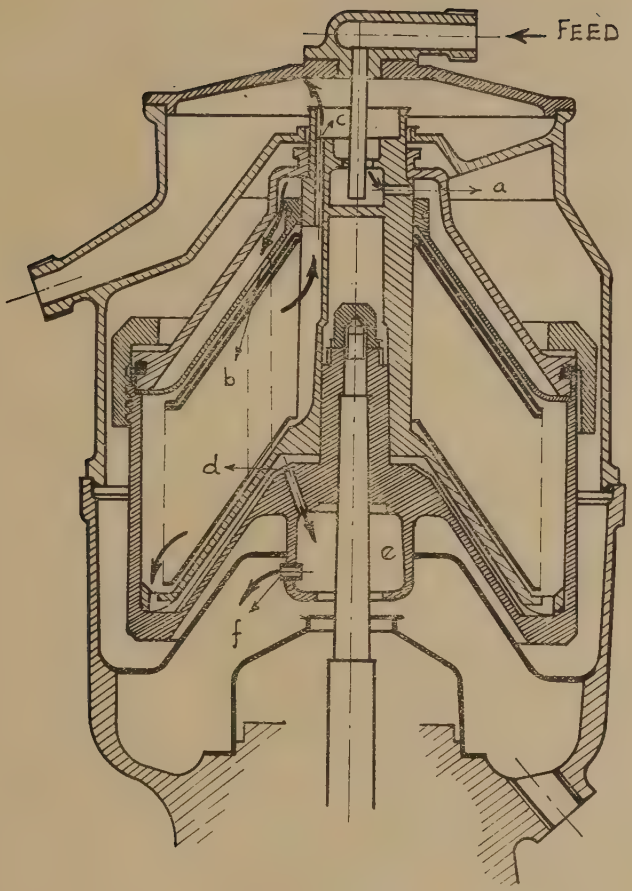
45 minutes for cleaning the bowl of this machine owing to the large number of plates.

Almost simultaneously with these tests, experiments with a similar machine were carried out in Sumatra and have been reported by Schrieke (1939).

Titan Machine

The Titan machine is manufactured by the Titan Company of Copenhagen. It is structurally similar to the machines already reported and consists of a steel bowl containing 87 stainless steel plates. It is driven normally at 7,000 r.p.m. but the speed may with safety be increased to 8,000 r.p.m. The method of operation differs from the types previously described in that the feed latex enters the bowl at the top and travels downwards through the perforations in the separating plates, while the skim after reaching the annular space between the plates and the bowl wall is led back to the centre at the bottom of the bowl and discharged there. This is clearly shewn in Figure 5 which is taken from British Patent No. 434,263 dated August 28th, 1935 issued to Nyrop and Titan. The concentrate follows the usual course through the machine, and the discharge orifices are fixed. Discharge from the base of the bowl to the skim cup takes place through six screw jets which are bored eccentrically with 1.25 mm. holes, and control of the performance is effected by rotating the jets to bring the holes nearer to or away from the centre of rotation. No overflow outlet is provided. The plates are located on guides on the inner wall of the bowl, as in the De Laval machines.

Typical test figures for this machine are given in Table VI (p. 97). These were obtained in tests carried out at the Institute in collaboration with a research engineer from the manufacturing company. From these tests it was concluded that at a throughput of 450 lb. per hour concentrate containing 60 per cent of rubber could be produced under average conditions with an efficiency of 93 per cent, and that a running time of three hours could be relied upon before cleaning. In the machine tested it was impossible to remove the complete bowl for cleaning, and the bowl had to be removed part by part. This was a disadvantage since it caused a loss in possible operating time. It is understood that the bowl will be re-designed so that it can be lifted out as a whole to overcome this objection. A second objection is that with this design it is necessary to open the bowl and remove all the plates to alter the adjustment, whereas with other machines the settings can be altered by stopping the bowl and removing the collecting trays. This difficulty would not prove so serious



a Latex Inlet to Bowl
b Perforation in Top plate
c Concentrate Outlet from bowl
d Skim control Jets
e Skim collecting Cup
f Skim discharge

Fig. 5

TABLE VI

Experiment No.	Feed Latex d.r.c. (per cent)	Duration of Run (Mins.)	Concentrate		Skim		Throughput (lb. per hr.)	Efficiency (per cent)	Remarks
			Wt. (lbs.)	d.r.c. (per cent)	Wt. (lb.)	d.r.c. (per cent)			
T 1	38.62	242	968.5	62.02	830	10.48	446	87.3	Concentrate d.r.c. remained steady. Skim d.r.c. increased from 7.9 to 13.5%. Efficiency fell from 92.7% to 82.8% during run.
T 2	37.6	180	729.5	60.8	514	5.00	415	94.5	Efficiency fell from 95.9% to 93.6% during run.
T 3	38.7	163	725.5	60.6	485	5.31	446	94.5	
T 4	31.26	150	571	57.0	557.5	4.35	451	93.1	
T 6	39.33	186	863.5	58.6	531	4.64	450	95.4	
T 7	31.38	160	570	61.7	641	5.04	454	91.9	
T 8	30.96	200	689.5	60.55	733.5	4.21	427	93.2	
T 9	31.55	180	675.5	59.58	705.5	4.69	460	92.4	
T 10	31.39	180	673	58.23	655	4.14	443	93.8	

in commercial working as it may at first appear, since once the best setting for a particular estate latex has been determined alterations should seldom be necessary. The machine under test took approximately eight minutes to reach speed, and one hour to stop, clean and restart.

Vickcen Separator

The Vickcen Separator, made by British Separators Limited, was tested by the author in the laboratories of the Rubber Research Institute of Malaya in 1936. The machine was similar in design to that shown in Figure 1, with 52 tinned steel plates and could be rotated at from 6,000 to 7,000 r.p.m. Separate adjustments were provided on both cream and skim outlets, the former by means of nozzles with variable projection into the neck of the top plate, and the latter by means of interchangeable annular discs having different internal diameters. It was found that the best average setting gave concentrate of 60 per cent dry rubber content with skim of 10 per cent dry rubber content at an efficiency of 86 per cent with a feed rate of 500 lb. per hour. The performance fell off very rapidly during the run and 800 lb. of field latex was the maximum quantity which could be treated before the bowl choked and had to be cleaned. Choking was due to an accumulation of thick buttery concentrate in the annular space between the inner edges of the plates and the distributor tube. The results will not be dealt with in greater detail here since a summary of them has been published (Piddlesden, 1937) and the manufacturers did not proceed further with the development of machines for latex concentration, so that as far as is known there are no commercial models of this make available.

De Laval Machine—Model L 1970

This machine is a larger edition of the L 770 machine with a bowl of approximately 14 inches diameter containing 68 stainless steel separating plates. The machine has a rated capacity of 880 lb. per hour but feed rates lower than this are usually employed. With average field latex fed at the rate of 750 lb. per hour the machine can be expected to give 60 per cent concentrate, and skim of 5 to 9 per cent dry rubber content with an efficiency of approximately 88 per cent, that is, with slightly higher efficiency than the smaller model. The machine can be run for approximately 3¼ hours and can be stopped, the bowls changed and run up to speed again in 18 to 20 minutes. The dirty bowl can be cleaned in 45 minutes.

Sharples Machine

The machine built for latex concentration by the Sharples Corporation of Philadelphia is of entirely different design from those already described. The bowl consists of a stainless-steel tube four inches in diameter and three feet long driven from the top at 15,000 r.p.m. It contains a cage into which a set of 80 curved radial vanes reaching the full depth of the bowl are fitted. Latex is fed into the bottom of the machine through a water-lubricated hollow trunnion bearing, and the concentrate and skim are discharged at the top of the machine into collecting trays in the usual way. The concentrate outlets are fixed and the machine is controlled by removing the annular disc over which the skim discharges and fitting one of different aperture. Every part of the bowl which comes in contact with the latex is of stainless steel.

The performance of the machine is said to fall off very rapidly as the run proceeds and it is not therefore practicable to run it for more than an hour before cleaning, although it would probably run for 1½ hours or more without becoming choked. The average efficiency in commercial operation to produce a concentrate containing 60 per cent of rubber with a feed rate of 450 lb. per hour is approximately 85 per cent. The bowl accelerates to speed and stops very rapidly, and is light enough to be removed without the assistance of tackle so that bowls can be changed in four or five minutes. A dirty bowl can be opened, cleaned and re-assembled in about 25 minutes. The power consumption is less than for other types of machine.

The Technique of Concentrating Latex on Estates

Feed Latex

It has been shown that slightly better separation can be obtained if the latex is aged for a few days before use, during which period some of the sludge can be removed by sedimentation, but it is usual to separate the latex immediately after collection since the saving in storage space and in ammonia outweigh the advantages of ageing. An ammonia content of 0.3 per cent in the feed latex is sufficient to preserve it for 24 hours. More must be used if a long period of storage is adopted, but since a large proportion of the original ammonia is lost in the skim fraction the cost is correspondingly higher. The ammonia should be introduced as early as possible, preferably in the field. Gaseous ammonia is more economical than ammonia solution and by its

use dilution of the field latex is avoided, but it is impossible to add gaseous ammonia to latex in the cups or collecting buckets. The best practice is therefore to issue to each tapper a small quantity of five or ten per cent ammonia solution for use in the tapping cups or collecting buckets. The latex from areas adjacent to the factory can then be carried in by hand, sieved directly into the feed latex tank and gaseous ammonia can be added to bring the concentration to 0.3 per cent. For more distant areas, field collecting stations are established where the latex is sieved into mobile tanks and preferably 0.25 per cent of gaseous ammonia is added, or alternatively a little concentrated ammonia solution may be used. The tanks are conveyed to the factory by lorry where the incoming latex is bulked in the feed tank and the ammonia content finally adjusted. The transportation tanks should be of mild steel coated on the inside with wax or one of the special bitumastic paints now available for the purpose. It is desirable to arrange a gravity flow throughout the concentration process, and a raised feed tank may be necessary, in which case the transportation tanks should be built to withstand sufficient air pressure to blow the latex up to the feed tank. All tanks and pipe lines should be designed to facilitate cleaning.

The feed tank can be open-topped or fitted with a loose cover if gravity feed is used. It can be of steel lined with wax or painted, or of concrete lined with glazed tiles. It may be divided into several sections and should be large enough to hold about two days supply of latex, to provide storage space in the event of a breakdown. The tank should be designed to drain to an outlet at the lowest point and a second outlet should be provided slightly above this so that latex can be run off from the upper outlet without disturbing the layer in the bottom of the tank. The volume between the two outlets should be about five per cent of the usual volume of latex placed in the tank. In this way the latex can be allowed to settle while the machines are running. The last five per cent of the volume will contain the bulk of sludge and can be concentrated at the end of the working period after first clarifying if this is necessary. This procedure should help to keep the bowls cleaner and give a longer average running time between cleaning intervals.

Machines

The machines are a heavy item of capital expenditure and in order to keep this to a minimum it is best to operate the plant on the basis of a 24-hours working day. It is therefore suggested that sufficient machines should be provided to concentrate the average daily crop in 18 to 20 hours of normal running. This will

TABLE VII

Machine Name	Westfalia	Titan
Manufacturer	Ramesohl and Schmidt, Oelde, Germany	Titan Company, Copenhagen, Denmark
Price July 1939	£280 c.i.f. Malaya, complete with motor.	£300 approx.
Spare Bowl (July 1939)	£120 c.i.f.	£150 approx.
Present Price (April 1940)	Not now obtainable.	£415 f.o.b. Copenhagen,* without motor
Price of Spare Bowl (April 1940)	—	£230 f.o.b. Copenhagen
No. of machines which can be served by one spare bowl.	3	Machine has fixed bowl
Materials of construction	Tinned Steel. (Stainless steel plates £60 extra)	Tinned Steel with stainless steel plates
Method of Drive	Motor or line shaft	Motor or line shaft
Power consumed approx.	5 H.P.	3.5 H.P.
Capacity lb. input per hour	450	450
Cream D.R.C. per cent	60 (or over)	60
Skim D.R.C. per cent	2—4	5
Efficiency	96	93
Running Time (mins.)	180-210	180
Time to stop, change bowl and restart (mins.)	17	—
Time to clean bowl (mins.)	45	60 minutes to stop, clean and restart

N.B. The figures quoted for the De Laval L 1970, and the Sharples separator of these machines.

* See footnote on page 85.

De Laval L 770	De Laval L 1970	Sharples
Aktiebolaget Separator Stockholm, Sweden	Aktiebolaget Separator Stockholm, Sweden	Sharples Corporation, Philadelphia, U.S.A.
£319 f.o.b. Stockholm, without motor	£618 f.o.b. Stockholm, without motor	£784 f.o.b. U.S. port, complete with motor
£172 f.o.b. Stockholm	£371 f.o.b.	£383 f.o.b. U.S. port
£414 c.i.f. Malaya,* without motor	£803 c.i.f. Malaya,* without motor	Estimated 30% increase
£223 c.i.f. Malaya	£482 c.i.f. Malaya	Estimated 30% increase
3	3	2
Tinned Steel with stainless steel plates	Tinned Steel with stainless steel plates	All stainless steel
Motor or line shaft	Motor or line shaft	High speed electric motor
3.5 H.P.	4.5 H. P.	2 H.P.
450	750—880	450
60	60	60
6—9	5-9	6—10
85	88	85
150	180	60
10	20	5
25—30	45	25

were compiled from data supplied by the manufacturers and by certain users

leave sufficient spare capacity to deal with peak crops and hold-ups and time to clean the feed tanks, latex pipes and flumes etc. before the next batch of latex arrives. Latex is usually received in the factory about mid-day and if work is done only in the daytime it means that each batch must be split, a part being concentrated in the afternoon and the remainder the following morning. The machines are arranged in batteries with common feed tanks and collecting tanks for the products, and one spare bowl is used for several machines. In order to make this possible and at the same time keep down the maximum power load, the machines are started at intervals. This method however causes a loss of working time if the machines are to be run only for two short periods each day.

The machines may be driven from a line shaft or by individual electric motors. The latter method is preferred since close connection by vee belts and accurate speed control are possible, whereas from a line shaft long belt drives, which may be splashed with water and give trouble by slipping, are necessary. On most estates however, it is doubtful whether the advantages of separate electric motors will be worth the extra cost, since electric power is not usually available and must be generated on the estate by means of a diesel-generator set. For small installations the efficiency of generation by this means is fairly low, whereas by coupling the diesel engine directly to a line shaft the cost of the dynamo and motors can be saved, and the over-all efficiency of the drive will probably be higher.

The characteristics of the machines discussed in the first part of the paper are summarized in Table VII (pp. 101 and 102). All are mechanically sound and constructed by reputable companies and should have a long working life. In the case of the Westfalia machine the tinned steel separating plates may show fairly rapid wear and it is desirable to pay the extra price for stainless steel plates.

The machine efficiencies quoted are for the concentration only. Each time a machine is stopped for cleaning the residual latex in the bowl is added to the skim fraction, but a certain amount of mechanical loss of latex occurs during cleaning. The magnitude of this loss depends on the care with which the installation is operated, but it is estimated that the over-all efficiency would be about two per cent below the machine efficiency. Similarly the throughput rates given are for actual running times, and allowance must be made for the time required to change bowls in order to obtain the daily throughput of the battery.

Lifting tackle must be provided in the factory to facilitate the removal of the machine bowls and adequate provision must

be made for benches and washing tanks so that the bowls can be opened, cleaned and re-assembled without loss of time.

Concentrate

Ammonia must be added to the concentrate immediately after preparation to raise the content of preservative to at least 0.5 per cent. The concentrate must also be mixed to form a large uniform consignment. If gravity flow is possible the concentrate may be allowed to pass directly to a large bulking tank into which ammonia gas is bubbled either intermittently or continuously depending on the volume of latex being produced. Where gravity flow cannot be used the concentrate may be collected in a small tank into which ammonia gas can be introduced; the liquid can be raised subsequently by air pressure to the bulking tank. Two such collecting tanks should be available, so that each can be emptied in turn without stopping the machines. The bulking tank or tanks should be as large as possible and should be equipped with an efficient slow speed stirrer and have facilities for introducing gaseous ammonia. They should be arranged so that the latex may be fed by gravity into the railway tank waggons or steel drums used for shipment. For a large estate from which shipment in bulk may be anticipated 10,000 gallons is a convenient size for a single bulking. For a small estate from which only drum shipments are contemplated 2,500 gallons, sufficient to fill 50 drums, is regarded as the minimum permissible size for a single bulking, but 5,000 gallons is preferable. The importance of bulking and mixing thoroughly in sufficiently large lots cannot be overemphasised, since consumers attach great importance to securing concentrate in large uniform consignments. A horizontal cylindrical steel tank, suitably protected with wax or paint and having propeller stirrers in one or both ends, is a convenient form of tank for bulking and mixing. The ammonia and dry rubber contents of the concentrate in the bulking tank should be checked each day and the machines so adjusted that the tank when filled contains material of the desired rubber content with at least 0.5 per cent of ammonia. Bulking tanks should be duplicated so that one consignment may be mixed, sampled, and packed for shipment while the second tank is being filled.

The best and most economical method of shipping concentrate is in steamer tanks. This necessitates transport by railway tank waggons or lorry, and the provision at the port of large-capacity storage tanks. Such an installation is beyond the scope of any but the largest producers, operating individually, and until some co-operative system is available most

producers will find it best to ship in steel drums each holding about 450 lb. of concentrate.

Skim Fraction

The best means for disposing of the dilute skim fraction is perhaps the major problem in the centrifugal concentration process. The cost of recovering this rubber increases with the efficiency of the machines and the diminishing concentration in the skim fraction. From skim containing above 10 per cent of rubber smoked sheet can be produced satisfactorily by coagulation with magnesium sulphate and sodium silicofluoride mixtures (Hastings, 1934), which can also be used to form a coagulum suitable for crepe manufacture from skim containing as little as five per cent of rubber. Alternatively the liquid may be stirred to remove the bulk of the ammonia and allowed to coagulate by fermentation, the coagulum thus formed being worked up into a low grade crepe. This method is cheap but introduces undesirable putrefactive bacteria into a factory where high-grade concentrate is being produced. With skim of very low rubber content recovery is extremely difficult and the resulting product may contain a large proportion of non-rubber solids. An interesting outlet for skim is to use it as fertiliser thereby utilising its nitrogen and phosphate content. If the soil is buffered on the acid side the liquid may be poured directly on to it, but for neutral or alkaline soils the ammonia should be first neutralised with sulphuric acid.

Economics of Centrifugal Concentration

It is not proposed to quote any figures for the costs of latex concentration by centrifugal means, but merely to outline the factors which should be considered in evaluating them.

Assuming a machine efficiency of 92 per cent the factory efficiency may be taken as 90 per cent. Thus for every 100 lb. of rubber in the field latex brought to the factory 90 lb. will be produced as concentrate. Of the remaining 10 lb. about 9 to 9.5 lb. will be present in the skim fraction, which may or may not be worth recovering; the remainder will be actual physical loss in washings. Further, in order to obtain 100 lb. of rubber in the field latex at the factory, approximately 108 lb. of rubber must be obtained from the trees, as tree scrap, cup lump etc. will account for about eight per cent.

The economics of rubber recovery from the skim fraction are bound up with the operation of the Rubber Restriction Regulations. When the permissible export is low, the value of rubber without export rights is low in the producing countries, and it is probably most economical for the producer to tap sufficient rubber to use all his export rights for concentrate and to discard the skim. An increase in the permissible export quota will increase the local

price of rubber without rights up to a point where it pays to recover the surplus rubber from the skim and to sell it locally, while still using all the export rights for concentrate. With a higher quota release the estate may reach a point at which it is impossible to produce sufficient concentrate to utilise the available export rights and must work up the skim rubber for sale with export rights in order to produce its allotted quantity and avoid reduction of the estate assessment. All such skim rubber is tough and hard and contains an abnormally high proportion of serum solids. It is regarded by consumers with suspicion and usually commands a price well below that for standard qualities. It is however possible that its exceptional properties such as high rate of cure may be found particularly suitable for special applications.

The quantity of ammonia used should be sufficient to provide for a concentration of 0.3 per cent in the field latex and at least 0.5 per cent in the concentrate. Thus for 100 lb. of rubber reaching the factory as latex with a dry rubber content of 33 per cent, 0.9 lb. of ammonia is required. This will yield 90 lb. of rubber as 60 per cent concentrate, *i.e.* 150 lb. of concentrate containing about 0.15 per cent of ammonia, and requiring a further 0.53 lb. of ammonia for preservation. Thus, allowing for loss, each 100 lb. of rubber or 300 lb. of latex entering the factory requires 1.5 lb. of ammonia.

Approximate estimates of the power required are given in Table VII. For operating the machines it is estimated that the number of labourers required will be one more than the number of machines used, for each of three shifts, if the 24 hours working is adopted. The cleaning times given are based on the assumption that two men are engaged on cleaning. Two men are essential to remove, open and re-assemble a bowl in each of the machines described, with the possible exception of the Sharples. The machines require little attention while working, and for a large installation one man per machine should be sufficient. In addition an engine driver will be required for each shift to operate the power plant and one of these men, preferably the one on the day shift should be a well-trained mechanic, capable of lubricating the machines, attending to the belt drives and carrying out general service work on the battery of machines. A responsible overseer will be required to keep all records and to carry out the determination of dry rubber and ammonia contents. Extra labour will be required in the day-time for cleaning the feed tanks, receiving the incoming latex, and packing the concentrate for dispatch. If the run can be finished in 20 hours the men operating the machines can be used for cleaning and to assist with latex reception. The labour required

for packing the concentrate will depend on whether drum shipments or bulk shipments in railway tank waggons are made.

Bulk shipment in steamer tanks is obviously most economical since the cost of steel drums is saved and there is no waste cargo space as in stacking drums. This method necessitates special installations for the latex both at the port of shipment and the port of entry and such arrangements are only warranted for large outputs. For many applications concentrated latex is required only in comparatively small quantities, and thus latex packed in steel drums each holding about 450 lb. finds a ready market. The drums should be treated with a protective paint or film (Rhodes and Sekar, 1935) to prevent discolouration of the concentrate.

Quality Standards and Testing

Preserved concentrated latex should reach its destination with the specified dry rubber and ammonia contents, and should be of good white colour, and free from coagulum, dirt, sludge and putrefactive odour. These are the present standards demanded by the market. Manufacturers have found however that latex fulfilling all these conditions is still a very variable raw material, and thorough mixing and bulking in large consignments is therefore important. Much research work has been carried out on improvising tests for assessing the quality and properties of latex. Measurements of stability to mechanical stirring, stability in contact with compounding ingredients such as zinc oxide, hydrogen ion concentration, content of non-rubber solids, sludge content, viscosity etc. have all been proposed as quality tests for latex, and the producer must look forward to the day when he may be called upon to meet closely specified limits in one or more of these properties.

References

Van Gils. (1939)	*Archief voor de Rubbercultuur* **23**, No. 1, 29
Hastings (1934)	*J.R.R.I.M.* **5**, 351
K.D.P. Ltd. (1926)	British Patent 243016, September 2
Metallgesellschaft A. G. (1932) ...	British Patent 382253, October 20
Piddlesden (1937)	*J.R.R.I.M.* **7**, 169
Rhodes and Sekar (1935)	*J.R.R.I.M.* **6**, 81
Schrieke (1939)	A.V.R.O.S. Proefstation Circular No. 150
Semperit (1938)	British Patent 492030, September 12
Ten Broeck & Schrieke (1940) ...	*Archief voor de Rubbercultuur* **24**, No. 2, 30
Traube (1924)	British Patent 226440, December 24
Utermark (1923)	British Patent 219635, July 28

Kuala Lumpur,
15th April, 1940